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MATTER AND ENERGY

THE concepts of matter and energy are the results of scientific analysis of the physical world and the most fundamental concepts in terms of which the events of that world can be construed. In the philosophic study of such concepts the primary need is a close inspection of the realities that they denote, for all concepts, if they are not sterile, must denote some sort of reality, and it is the nature and value of this reality that primarily concerns us as metaphysicians. Our materials are, then, the researches of the scientists, and these are to be understood as closely as possible to the way in which the scientist understands them, that is, with the least possible corruption through philosophic presupposition. If our results are in opposition to utterances by scientists, they will not be opposed to the scientists' facts and practise, but only to the somewhat hasty and often antiquated philosophic points of view which men, most painstaking in other matters, so often inconsiderately interject into their work.

The history of the atomic concept has been too long and complex to receive detailed consideration here, for atoms have been imagined since the dawn of history. In the Soutras of India, probably before 1200 B.C., Kanada defines substance as "that in which qualities abide and in which action takes place. Earth, water, light, air, ether, time, place, soul, mind, such are the substances." To the first five of these is attributed atomic structure. The atoms are simple and indivisible else "there would be no difference of magnitude between a mustard seed and a mountain, a gnat and an elephant, each alike containing an infinity of particles."[1] Probably independently of this, atomic theories arose early in Greek thought and since, as Bacon wrote, "Men cease not from abstracting nature till they come to potential and uninformed matter, nor on the other hand from dissecting nature till they reach the atom."[2] But we are now primarily concerned with the use of the concept since the epoch-making work of Dalton,

[1] Freund, *The Study of Chemical Composition,* pp. 229–30.

[2] *Novum Organum.*

for it was Dalton who first transformed it into a valuable instrument for experimental science.

The primitive suggestion, as it appears in Kanada and even more clearly with the pre-Socratics, is the need of finding something permanent and abiding so that, with the aid of varying relations, change can be described. The fact that practical needs compel us to treat realities as in some way the same, although changed, is the cue to the structure of logical thinking even more than the spectacle of the Heavens so ardently apostrophized by Poincaré,[3] for through it, the distinction of terms and relations becomes manifest, and from the application of this distinction to the analysis of the physical world, some form of the atomic conception must have arisen even without the model of the starry heavens above, and through it also, the development of atomic theories is controlled with a concreteness that Poincaré's more poetically inspiring model could never have compelled.

Dalton's achievement is that of giving an empirical character to the terms and relations suggested by atomic analysis. To make this evident it is only necessary to review the specific points of his hypothesis. He writes (1) "I should apprehend there are a considerable number of what may properly be called elementary principles (atoms), which can never be metamorphosed one into another by any power we can control. We ought, however, to avail ourselves of every means to reduce the number of bodies or principles of this appearance as much as possible; and, after all, we may not know what elements are absolutely undecomposable and what are refractory, because we do not apply the proper means for their reduction." In other words, there are different kinds of atoms distinguishable by their properties and actions. (2) "Matter is not infinitely divisible." This seems to have been a logical postulate for Dalton, but has proved itself experimentally valid within the field of chemical process as he understood it. With it is associated the next principle, (3) "No new creation or destruction of matter is within the reach of chemical agency. We might as well attempt to introduce a new planet into the solar system, or to annihilate one already in existence, as to create or destroy a particle of hydrogen." And so far we are merely in line with the current historical form of atomism of his day, but the remaining assertions give concrete additional properties that are sufficient to transform the status of the whole conception. (4) The atoms have characteristic weights, (5) they combine in simple numbers, and (6, 7) their relative weights and the complexities of compound atoms (molecules) and their rules of chemical synthesis may be determined. The atomic theory, then, has come to give us a set of empirically determined terms and relations with the marked advantage over the old that by them observed changes can be predicted and controlled and empirical verification, at least by indirect observation, found.

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[3] *The Value of Science*, Ch. VI.

To-day the atomic analysis of matter is being transcended, yet, with the exception of certain determinations of specific characteristics, the hypothesis of Dalton still stands. What has happened is that a closer contact through experiment with the behavior of material substance has indicated that the atom represents only a stage of analysis and that, for the study of certain processes such as phosphorescence, light, radio-activity, electric and magnetic phenomena, changes must be described that can not be expressed in terms of known atoms, but demand a more basic element out of which atoms may be constituted, and the electron has come to fill the place. Whether in turn this must give way to something still more minute is a question for the future of science to show, but at any rate, the type of analysis of the physical world will remain the same in so far as such analysis is retained.

The real existence of atoms and of electrons has been both denied and affirmed. Experimental evidence to-day seems to favor the affirmation, but the problem is not quite as simple as some of the experimentalists would have us believe. There is a delusive clearness about the alternative "real entities" or "physical postulates" and "hypothetical entities." We shall have to return to this problem again, but it can best be done when we have made a preliminary examination of that other concept so closely associated with that of matter, the concept of energy, and this concept will now concern us.

Energy is currently defined as the capacity to perform work, but, as far as observation is concerned, Hume might have pointed out that we find merely a means of correlating change in one part of our experience with changes observed elsewhere. If it asserted that it takes a certain amount of energy to raise a given object to a certain height, it is meant that there is an observable descriptive correlation between the mass and velocity of an associated body that is said to cause the effect and the effect produced. The simplest observable exhibition of energy is in the communication of motion by contact of a moving body with something that moves after the contact. For the ancients this movement was an inherent property of material substance or of some specific substance, such as the Nous of Anaxagoras, and this inherent property was "communicated" from one body to others. The term force is roughly used to cover the situation, and still remains popularly the name of a property by virtue of which changes are produced. But the term force is too general to cover the facts as they appear under detailed analysis and in modern science it becomes necessary to find a term to express in quantitative form the persistent correlation observable between the kind and amount of movement of the first moving body and that of the body to which movement has been "communicated," and for this purpose, early in the nineteenth century, Young introduced the term energy.

But the same study that leads to quantitative correlation, also brings out certain other features of the propagation of motion. Thus the motion of mass, a cannon ball for example, may result primarily in a motion of molecules when the ball hits an impenetrable armor plate, that is, in heat, but nevertheless, there is a definite qualitative relation between this heat and the mass and velocity of the moving ball. And besides these direct contact cases, there are a large number of cases where the propagation of change from one to another takes place when the bodies appear to be at a distance, as in gravitation, illumination, chemical affinity, and the like. Probably, because it is the way we work with our bodies, we accept contact effectiveness as needing no explanation, but seek hypotheses to cover the latter sort of propagation. However, the latter is no more mysterious than the former. It is merely less close to human behavior. Why should a billiard ball roll when struck by another, or an object move because it is pushed? To attempt a scientific answer in terms of solidity, resistance, elasticity, and the like has no more value than the explanation of the dormitive powers of opium through its soporific virtue. The only real answer is that physical reality behaves that way and at that point all our questionings must cease except in so far as we can attain description of our facts in increasingly general terms and discover an ever growing number of relations and correlations between them.

But the case of what appears naïvely as action at a distance demands further analysis. As far as unaided human observation is concerned, there are many instances where a change in one part of reality involves changes elsewhere. Closer observation shows that in many such cases, the introduction of something between the "cause" and its "effect" results in the propagating change being intercepted by the inserted body and taking place in it instead of at the point where it has originally appeared. The most simple example is the insertion of a screen between a source of light and the illuminated object, where the object loses its illumination and the screen receives it. We are then led to assume that the propagation of this change is really continuous between the two bodies and this hypothesis has served as a basis for a vast amount of scientific discovery. We are also led to assume the existence of some medium of which the propagated change is a mode of motion and the result is the ether concept, of which at present the sole characteristics are those introduced to satisfy a formula accounting for a connection of certain things whereby changes in the one involve changes in the other also.

The most striking feature of all scientific references to energy is the apparent necessity of conceiving it always as a case of something in motion, mass, molecule, atom, electron, or ether. The holding in check or distorting of certain normal motions through an outside agency or opposed tendency to motion, as when a spring is held wound, is what is known as potential energy, and the capacity to produce change while regaining or continuing normal motions, as when the watch is running, is the same energy in kinetic form. But it is always expressible in terms of something in motion or tending to move, and it is also noteworthy that the propagation of energy, whenever possible, is conceived as a contact push, either directly or by a medium. In a few cases pulls are also suggested though, at last analysis, these often reduce to some form of ether disturbance where the pull is like the suction behind a vessel moving through the water and really reducible to pushes. It is interesting also that the best of the tentative explanations of that most mysterious of all physical processes, gravitation, although hardly reaching the value of fruitful scientific hypothesis, have also been made in terms of push.

At last analysis, then we think of energy in terms of pulls and pushes, but except as a description of immediate experience, nobody knows what a pull or a push is. There is a tendency to feel the push as the more ultimate concept because experienced pulls always involve the presence of some kind of material connection, like a string, through which the pull becomes effective and in the case of theoretically detached objects, like atoms, molecules, and electrons, it is not so clear what takes the place of the string unless we introduce some conception such as that of ether strain of which the concrete meaning seems to be wholly undetermined by the chemists and physicists except in so far as to account for the phenomena they have in mind, that is, it is an entity defined purely hypothetically. The analogical suggestion is often that of currents in a liquid and this, of course, transforms the idea into that of push.

But if we accept the push concept as the ultimate are we then provided with something more intelligible? I think not. That the cue pushes the billiard ball is at best only a way of describing what takes place when a certain contact between a moving and a stationary object is made. It is again a case of a description of an immediate experience. Why should an object move when pushed? To answer in terms of its resistance to penetration does not carry us any farther toward an understanding of fact, for it is only to move circularly in terms of concepts already derived from description of experience alone.

This comment, however, is not meant to suggest an unknowable back of scientific reality as was done by Herbert Spencer, for against Spencer, Royce is quite right in asserting that the only things that are unknowable in an absolute sense are the answers to absurd or self-contradictory questions. Our only aim is to emphasize the functional and empirical basis of all knowledge. We must begin with a description of certain observed facts, whether we begin with a high and complex order of phenomena, as in studying the problems of the social sciences, or with the most minute phenomena that enter into the ultimate analysis of the physicist and chemist. And if we begin in this fashion, the only meaning of knowledge is to pick out relations discoverable between more complex phenomena that can be construed as complications of the elementary observated facts.

The facts that give rise to our concept of energy seem to indicate that change found in any part of the universe spreads to other parts in a fashion capable of definite qualitative and quantitative description. The principle of the conservation of energy is merely the universalizing of this generalization, an assertion of the effective unity of the whole. The principle, as Poincaré asserts, can not be definitely proved, but it is nevertheless a successful generalization of experience, on an equal status with any other empirical law. In other words we have in energy the physicists' expression of the contactual unity of the physical world, but to see the full consequences of this we must return to the analysis of matter with which we commenced.

The scientific world presents itself to us as a collection of elements, mass, molecule, atom, electron, which represent stopping-points in our efforts to analyze, and energies, or concrete formulations of the results to be expected elsewhere, as to kind and quantity, when a specific change takes place in any of these elements or in any group of them. But we must not falsely assume that we have here constituent elements and a world built up through different arrangements and combinations of them. Let us return to our concepts and see them with respect to the realities they denote.

First consider the atom with its affinities and valency. If we ask what it is, we are told that we have a collection of electrons having certain specific motions and, if our informant were sufficiently wise, he might tell us by what laws or general description of behavior, all its energies and substance properties result from the particular number of electrons, arranged in the particular way that make up its structure. The atom with its properties, has ceased to be a substance, but is an integrated group of substances, electrons, and their energies.

These electron energies have become part of the substance of the atom and the atom is really an entity in about the same sense that congress is an entity. Indeed, in so far as any "element" shows complexity of behavior, it is probable that it can be analyzed into a complex and it is highly doubtful whether our electron is as simple as now appears.

The historic problem of an ultimate element is the one that will suggest itself to most philosophers here, but to one who has comprehended the foregoing, the classic antinomy between the finite and infinite divisibility of matter will not be the starting-point. Resting-points in analysis are determined by the needs of human action, and what we are satisfied to call elements depend on the nature of reality as limiting and making possible our activities. They may vary as we acquire new ends, more elaborate technique, and closer observation. But reality, as such, is not divided by our analysis, but merely thrown into useful perspectives. If one were to attempt an absolute metaphysical assertion, it would be necessary to hold that reality is indivisible. Man may slice matter at his pleasure, but the connection of its parts that can be attributed to ether, gravitation, etc., are never severed or in any way interrupted, whatever significance the division may retain for human action.

If we ask, however, if our analysis must proceed infinitely, it can be replied that any analysis that fulfils the function for which analyses come into being will represent a finite resting place. The mathematical infinite and the transfinite are finite resting-points of analysis. The assumption that it would require "infinite complexity to grasp the real" that sentimental philosophy is wont to make, is merely based on the fact of the formal possibility that there should always be a purpose or attitude demanding a more complex analysis than any given finite analysis, but without empirical fact, it is idle to speculate on the possibility of such a situation. The concept of levels suggests, however, an ultimate pluralism in the sense that different needs can be fulfilled by different types of analysis, for, though scientific needs might be monistically satisfied, the entities built up of lesser entities in the monistic system have, with respect to us, wholly new uses that lend themselves to new types of analysis. An act of theft may have a psychological, biological, chemical, or physical explanation, but it invokes a response from us which is not a response of any of these types, but to the integration of processes that make the theft a new and unique sort of fact in our environment. Instead then of asserting the infinite complexity of the real, we can assert merely that any empirical analysis of reality will be finite, and that, due to the complex possibilities of human behavior, an indefinite number of such analyses may be made and that they are not necessarily reducible to a single analytic system. They are not contradictory to each other, but rather like divisions of the same material in accordance with different *fundamenta divisionis,* and if taken together, they make a confused mass of cross classifications, some omitting entirely what is fundamental to others and putting first what those consider in the last place.

The question as to the discovery of an ultimate element, then, becomes unimportant philosophically. If the scientists' concepts are the result of a human reaction on nature, the limits to which discrimination and subdivision must be pushed depend upon the closeness of human contact with the kind of facts in question. When our discriminations are adequate to enable us to handle predictively all of the facts with which directly or indirectly we may come in contact, we have elements that are ultimate for that particular branch of knowledge. Scientifically, the character of the processes discovered is infinitely more important than the problem as to whether or no the entities in terms of which they are construed are ultimate. Logically, our task only ends with entities that can be construed as simple, but this simplicity never has any meaning outside of the particular point of view of the logical analysis with which we are at the time engaged.

The scientist is after all much like a map-maker, for a map must be based on an analytical knowledge of the facts of the country mapped, and must have just that kind of relation to the facts that makes its features symbols capable of aiding an engineer about to build a railroad or a general directing a campaign, but no one would expect the country to be constituted of the things found in the map, as a house is built of bricks, or that the things shown by the map had an independent existence, or that they were unrealities; yet in the case of science each of these things has been claimed as a true account of what is denoted by its concepts.

Our answer to the question raised above (p. 59) is now obvious. Atoms, electrons, and the like can not be unreal or they would not possess the value necessary to fulfil their function in a body of scientific knowledge. They are not mere symbols, nor are they independently existing elements brought together to constitute a whole of reality. They are simply phases of physical existence that have exceptional value from the fact that through centering attention on them it is possible to state some process in lawful fashion.

Perhaps the most pernicious error in philosophic thinking, and even in the thought of many scientists, is that separation of matter and energy, which while justifiable in the sense that we can distinguish the shape of an object from its color, and insist that one is not the other, is wholly illegitimate, if we try to think as if the color and the shape are independent realities brought together in the particular object, instead of analytically derived aspects that have quite different practical values when it is a question of dealing with objects. If scientists have talked about "energy atoms," it is merely because the kind of contact we have with certain phenomena makes it impossible for us to find the "term character" in the source from which changes spread and so the resultant energy factors constitute the sole datum, and it becomes possible to beguile ourselves with the belief that here we have a geniuine disembodied energy.

The scientists' world is the real world, but with a qualification. It is a selected real world according to those aspects which are significant for a certain purpose. Unlike the artist, whose aim is expression, the scientist can not introduce what is not really there into a certain context, but he can preserve in that context only what is fruitful for a certain purpose. He is ever under the pressure of the need of prediction. The map-maker would certainly be wrong if his map did not denote realities, but he would just as certainly be absurd if, because he charted his territory in terms of rivers, mountains, valleys, and plains, he should assert that there was nothing else of which the landscape is made up. There is no such a thing as an atom in just the sense that there is no such thing as a river, *i. e.*, they are not found out of integral relation to other realities.

Our nature determines the constitution of this scientific world merely in the sense that it determines the possibilities of our action. If there could be an organism transparent to solids, but meeting light as a barrier and consequently finding its possibilities of movement in the interior of the planets, it would undoubtedly construe the universe after the model of a Swiss cheese with movable holes, but it would be the same universe that it construed, only the "map" would be made from a wholly different point of view. But a being that has processes of reaction and selective attention like ours must approach any physical universe through selected phases and not meet its continuities with continuities. Given this necessity, in a variegated universe where changes spread, some concepts of matter and energy are sure to arise, where matter is the name for the resting places of analysis, and energy for quantitative correlations of spreading changes among these material "atoms."

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